Predictability of Severe to Exceptional Droughts in Texas

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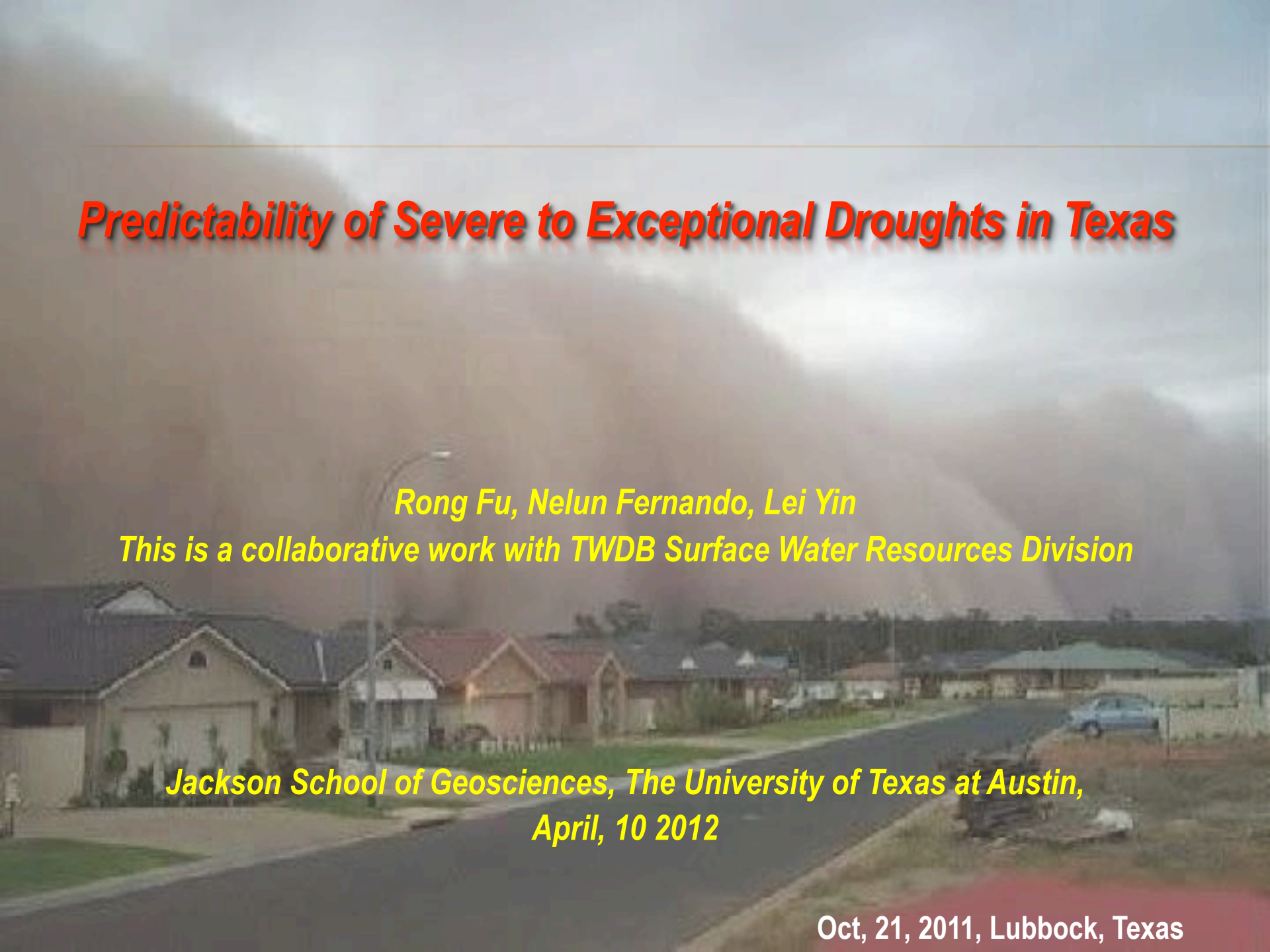
This is a collaborative work with TWDB Surface Water Resources Division

Jackson School of Geosciences, The University of Texas at Austin,
April, 10 2012

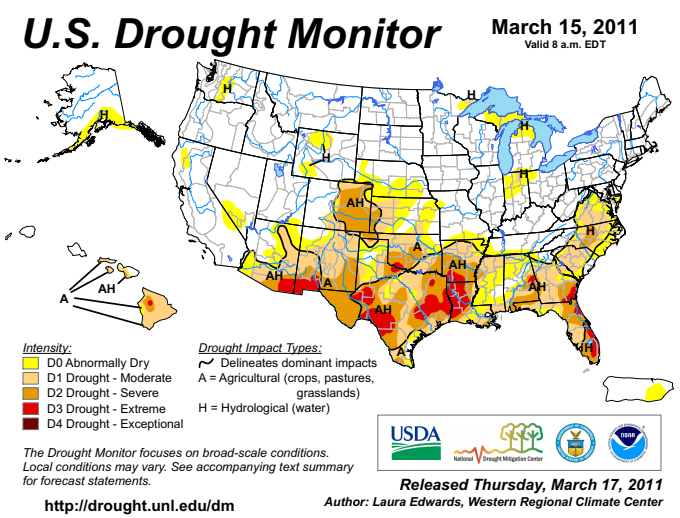


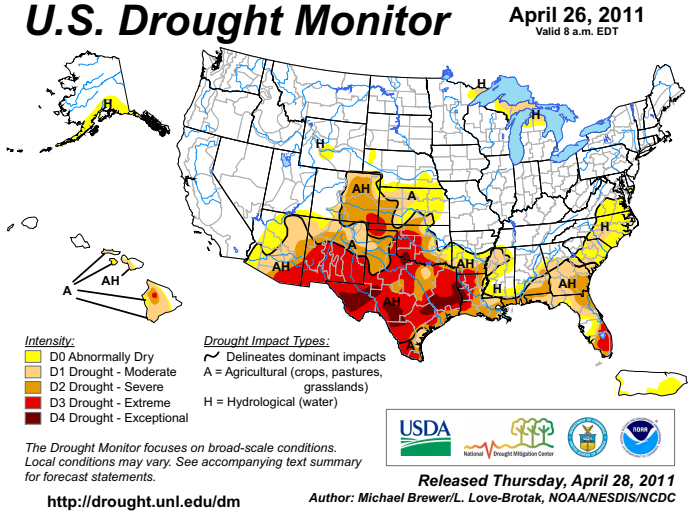
2011 Texas drought is among the most costly drought

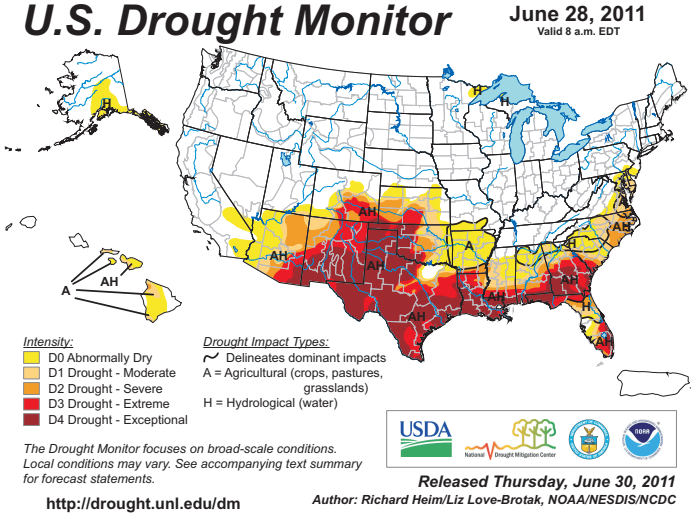
- *Agriculture loss: $7.62B (the Texas AgriLife Extension Service)*
- *Fires: 10 people died, including 4 four firefighters, burned nearly 3.7M acres and 1915 homes*
- *Loss of power generation caused rolling back-outs, threatened production of oil refinery (1/6 of the nation)*

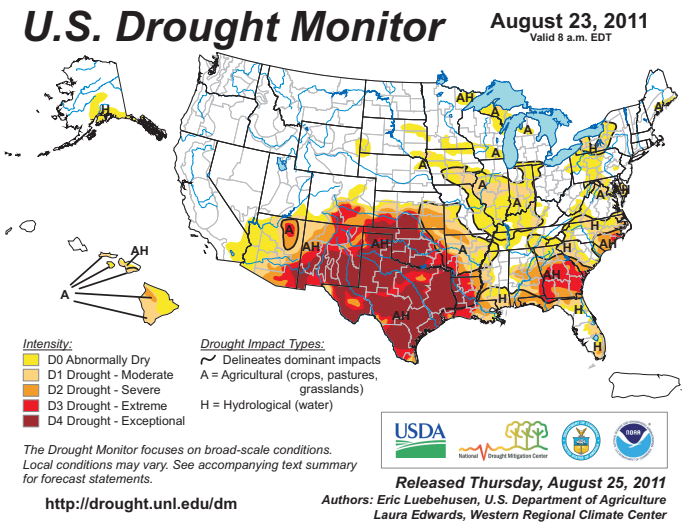
Evolution of the 2011 Texas Drought:

- **The drought intensified rapidly in late spring and summer.**





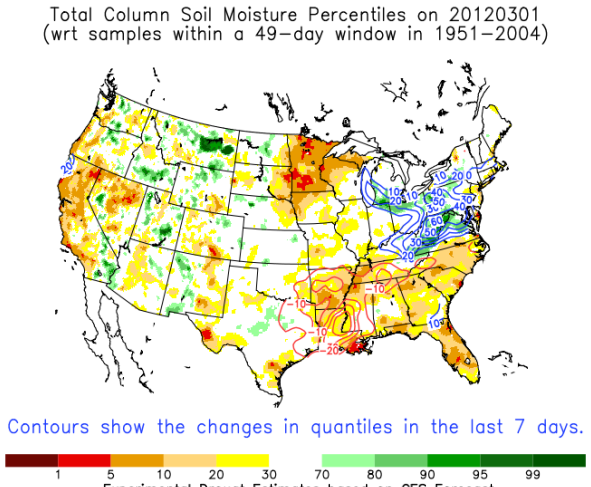


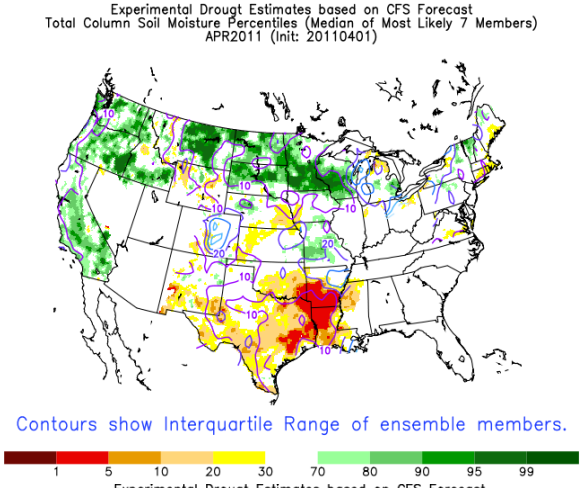


How well the 2011 drought was predicted?

- ***CFS most-likely and full ensemble predictions and EPS ensemble forecasts all fail to predict strong drought during summer of 2011.***

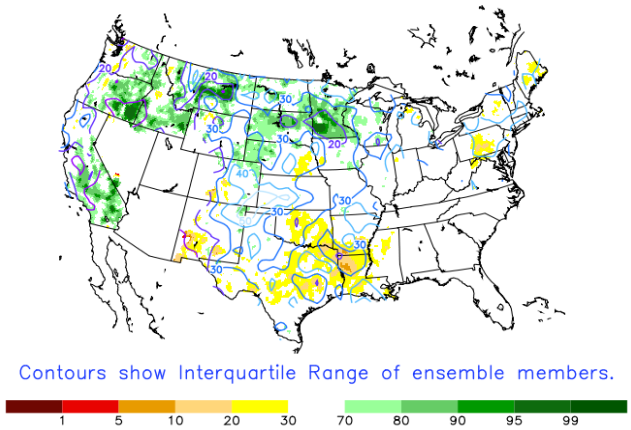
CFS: Initial soil moisture anomalies in March 31, 2011

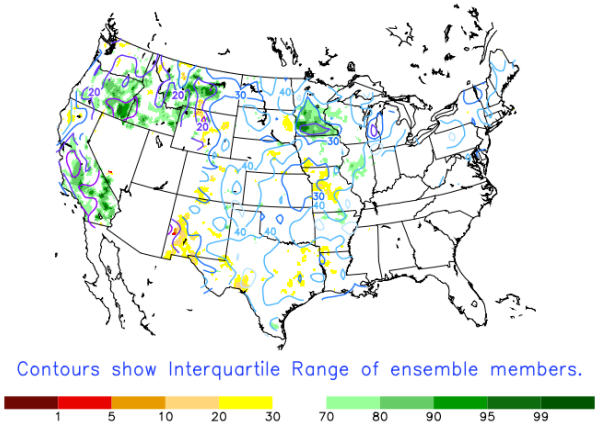




CFS most-likely: soil moisture anomalies in April, 2011

June, 2011



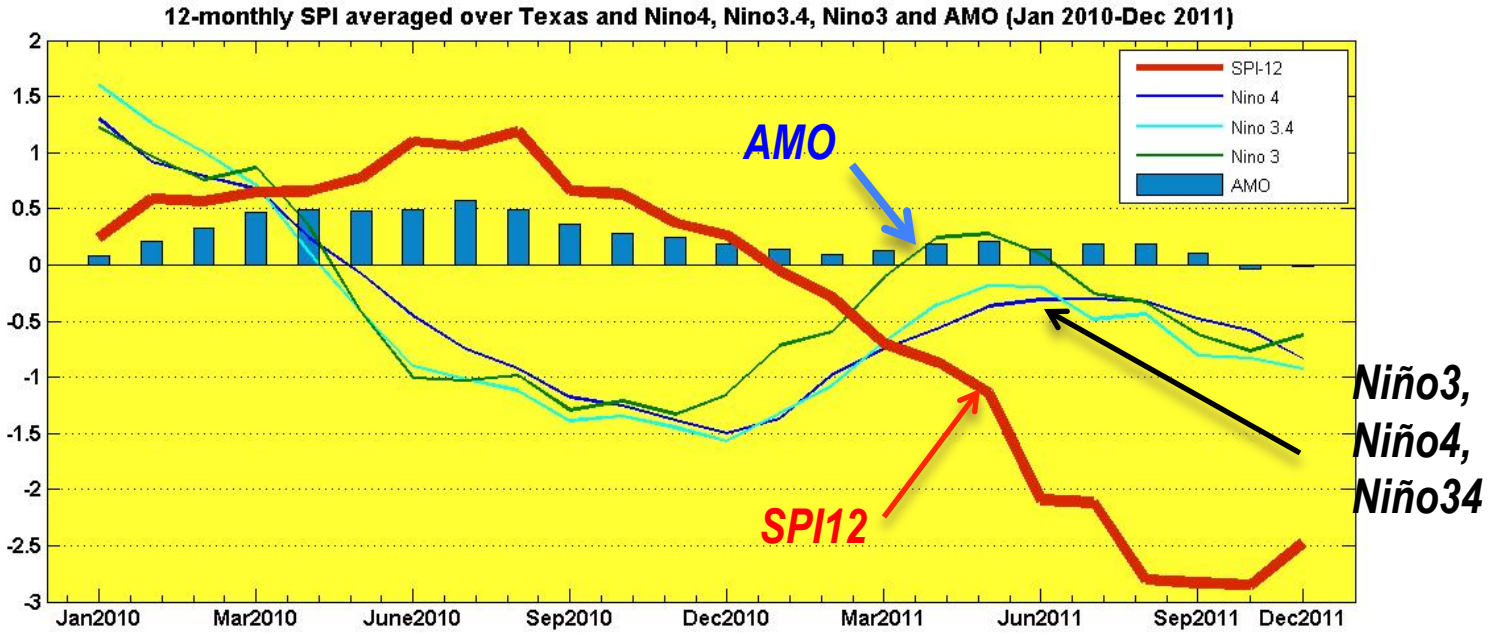


August, 2011

National drought forecast analysis, http://www.emc.ncep.noaa.gov/mmb/nldas/forecast/TSM/prob/

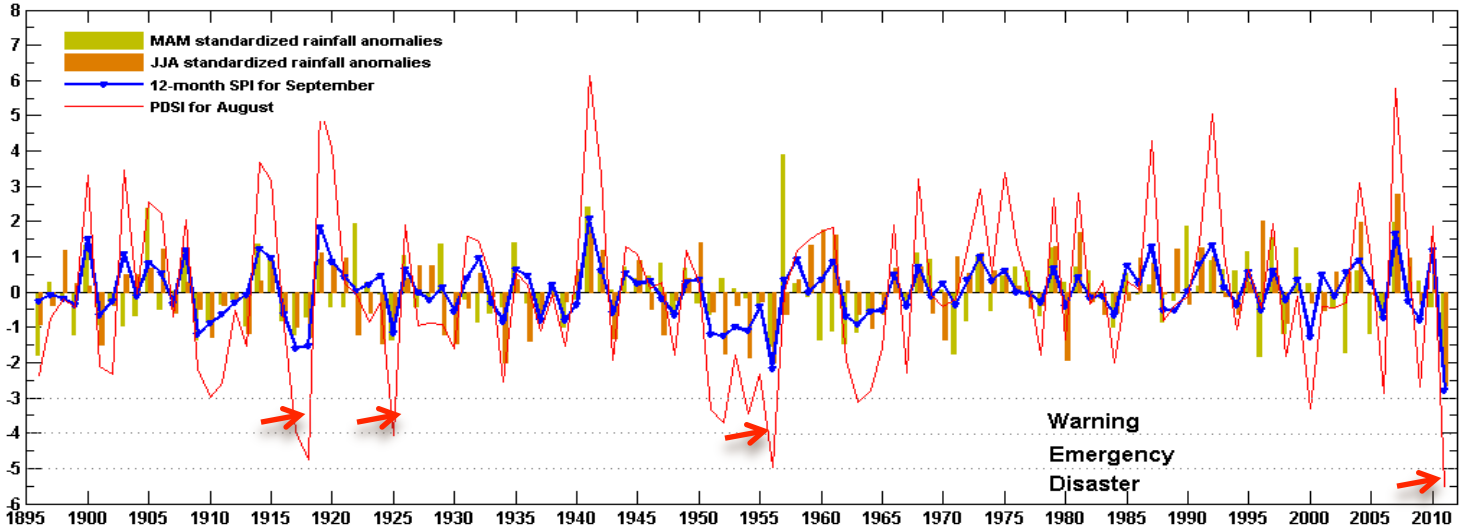
What caused the worst one year drought in 2011?

- *La Niña and AMO cannot explain why did drought worsen rapidly in spring and summer of 2011?*



What cause severe-exceptional droughts in Texas?

- ***Since 1895,***
  - ***16 out of 18 severe-extreme droughts had below normal rainfall last from winter (DJF), through spring (MAM) to summer (JJA).***
  - ***Since 1895, the worst summer droughts (1918, 1925, 1956, 2011) all contributed by rainfall deficits in spring.***



– *ESRL PSD 20th century reanalysis*

(Source: Fernando et al., in-prep.)

How can spring drought intensify summer droughts in Texas?

Myoung and Nielsen-Gammon, 2010, J. Climate:

- *Summer rainfall deficit over Texas is mainly caused by*
- *A higher CIN due to*
  - *soil moisture feedbacks*
  - *increase of cap inversion due to westerly advection of warm air from Mexican Plateau*
- *Enhanced upper-level anticyclonic flow, which reduce synoptic disturbance*

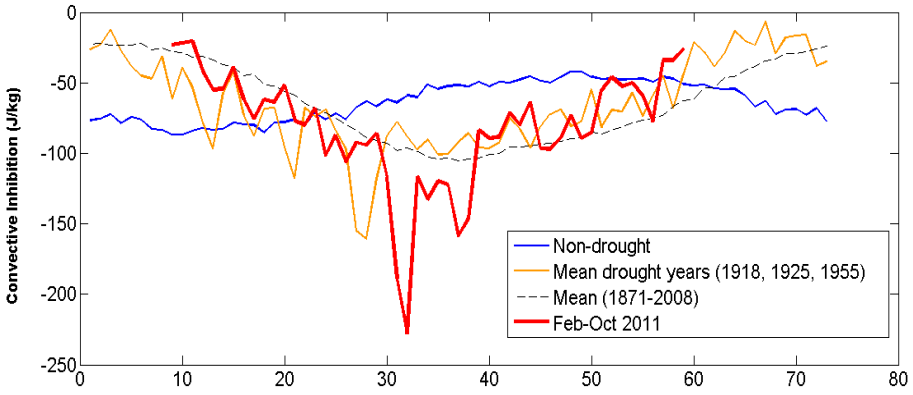
Questions:

- *What could cause 2011 exceptional drought in absence of strong La Niña and AMO influence?*
- *Could spring rainfall deficit initiate a positive soil moisture feedbacks and contribute to severe to exceptional summer drought over Texas?*
- *If so, could we identify the anomalous large-scale circulation pattern preferred by strong spring rainfall deficit? Is this anomalous pattern predictable?*

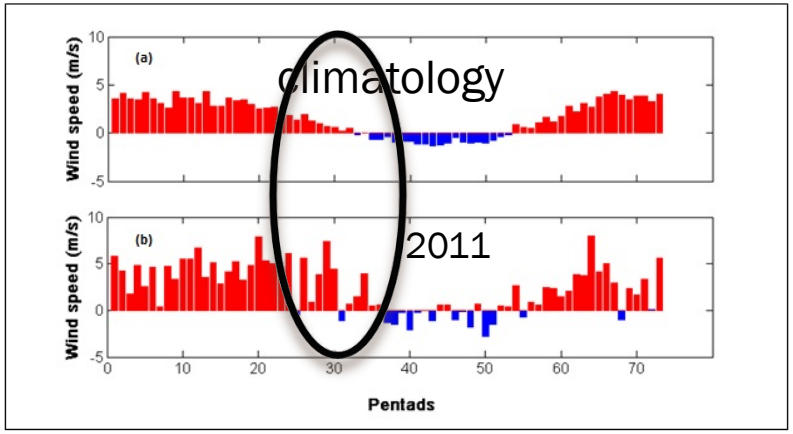
How importance is the spring condition to summer severe to exceptional droughts?

- *During the 2011 and other three strongest summer droughts over Texas since 1895,*
  - *Sharp increase of CIN in spring occurred prior to all four strongest summer droughts;*
  - *U850hPa was strong westerly, instead of transition into easterly.*

Convective inhibition (CIN)



Zonal wind at 850hPa (850hPa)



(a) Climatological area averaged April pentadal zonal wind, and **(b)** area averaged pentadal zonal wind in April 2011 within the domain 106°W-100°W and 30°N-36°N. Red bars depict westerlies and blue bars depict easterlies.

Data used:

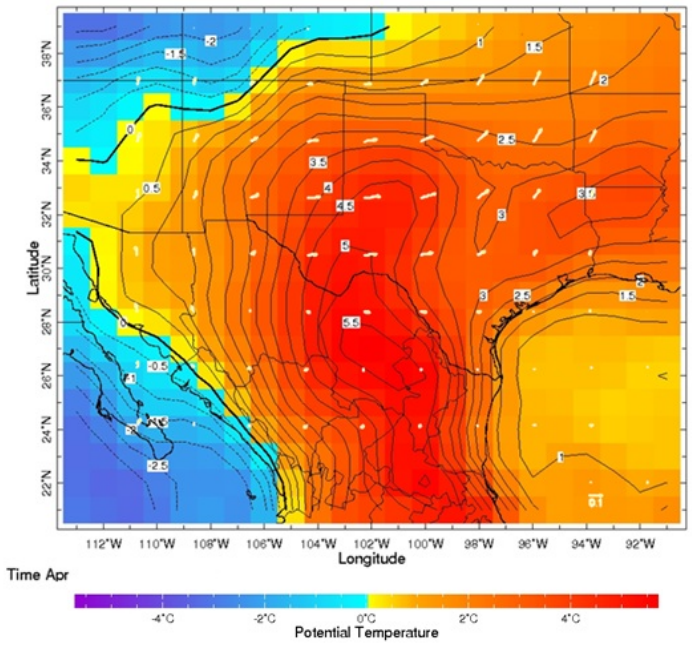
- Historical period – ESRL PSD 20th century reanalysis
- 2011 – CFSV2 real-time data

(Source: Fernando et al., in-prep.)

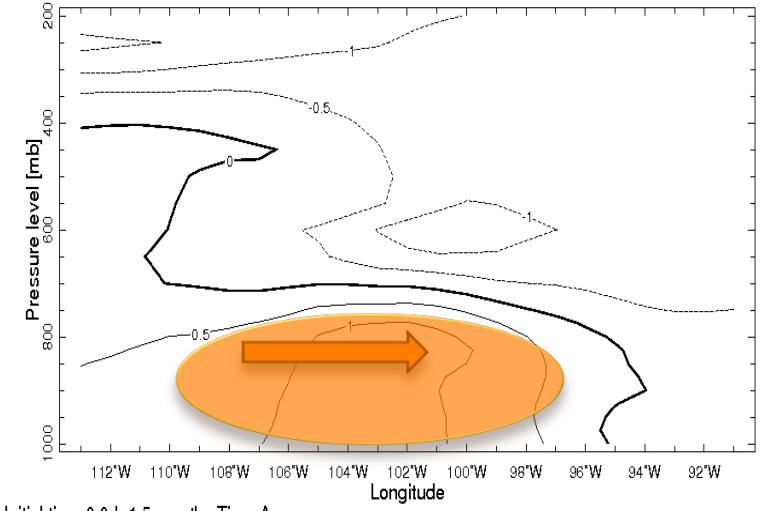
What caused sharp increase of CIN in spring?

- ***Warm air advected from Mexican Plateau and SW Texas increased capping temperature appear to be an important contributor to the sharp increase of CIN in spring.***

850 hPa wind April 2011



θ anomaly April 2011



Data used:

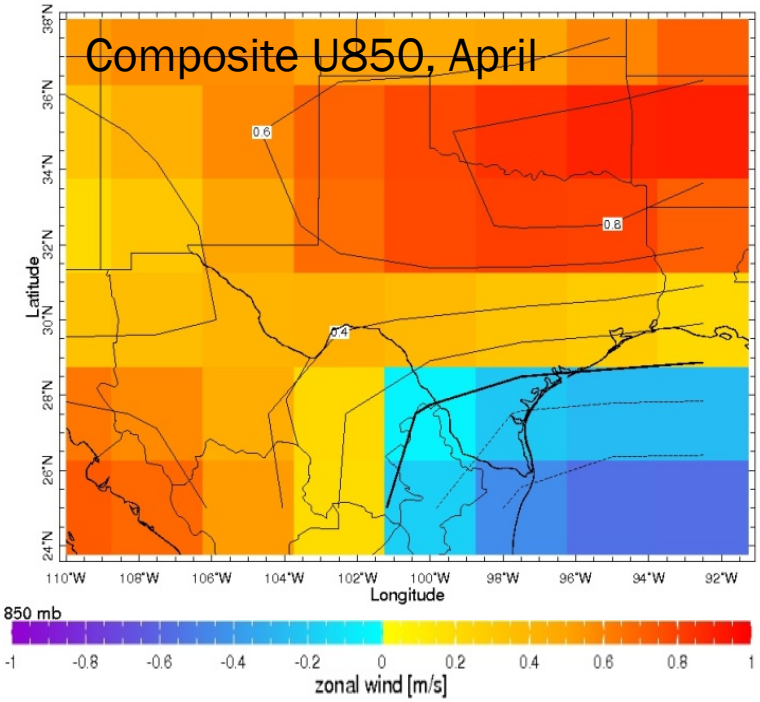
- 2011 – CFSV2 real-time data

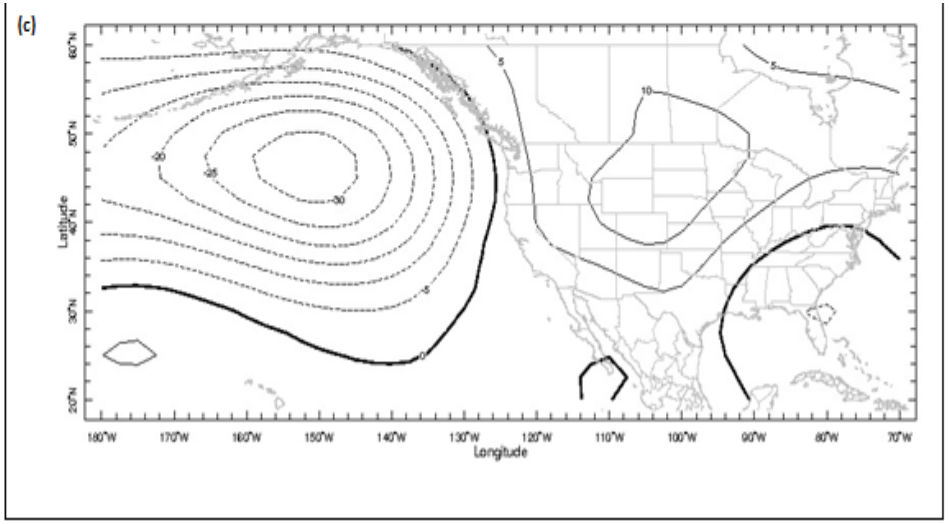
(Source: Fernando et al., in-prep.)

MAM(dry)|JJA(dry) is generally associated with westerly in spring.

- ***This wind pattern, averaged over all dry spring and summer years, shows westerly wind over Texas;***
- ***This wind pattern is part of large-scale atmospheric flow pattern linking to ENSO indices in spring.***
- ***Thus, it could potentially serve as a predictor of spring trigger of summer drought.***

Red: westerlies, Blue: easterlies



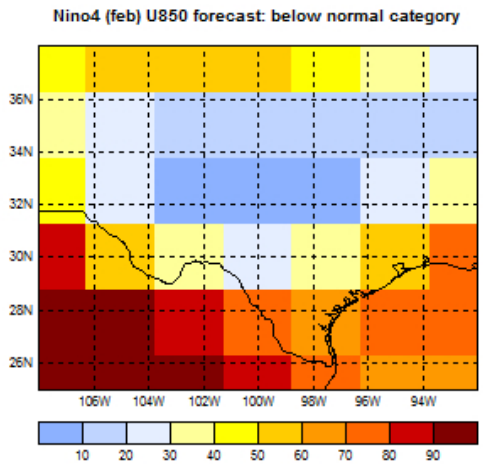


Canonical pattern of April 850 hPa Geopotential height that explained 92% of the variance of April zonal winds over Texas

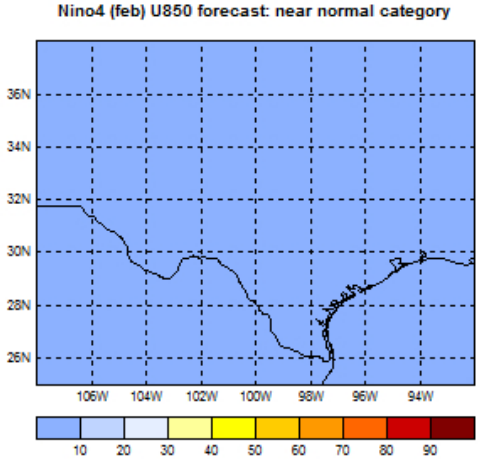
(*Source: Fernando et al., in-prep.)*

Hindcast of U850hPa in April 2011 using the observed statistical relationship and Niño4 index of Feb. 2011:

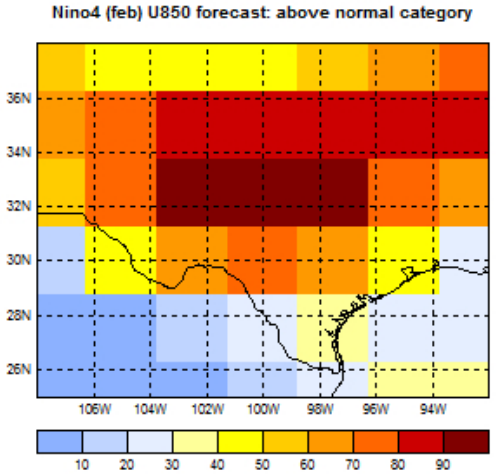
U850 forecast using Niño4 index for February



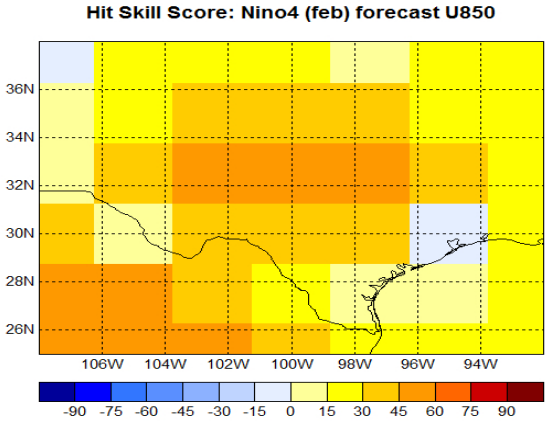
Below-normal



Near-normal



Above-normal

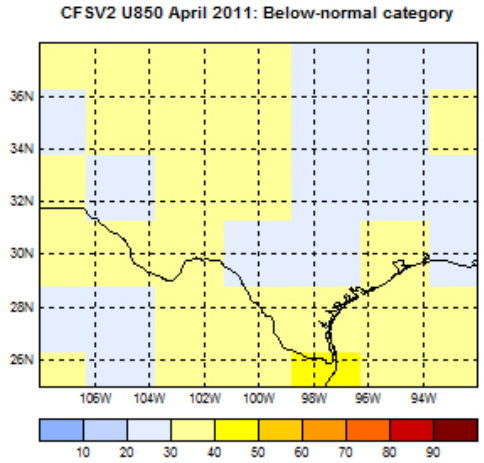


Overall skill: between 15-75% with central Texas Ranging from 45-75%. No skill in southeast corner. Similar to skill from Niño3.4(Feb).

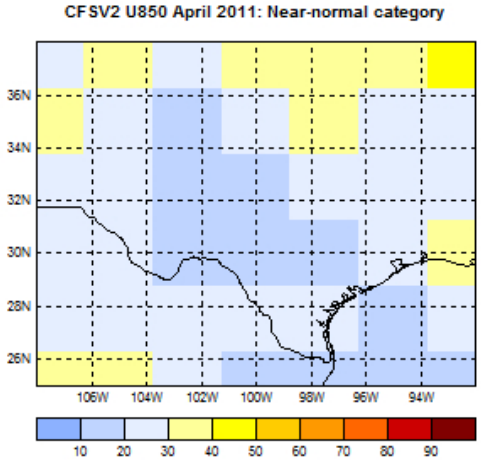
(Source: Fernando et al., in-prep.)

CFSv2 most-likely forecast predicted above normal westerly wind in April 2011 although it fails to predict 2011 summer drought:

U850 forecast using CFSv2 realtime monthly forecast of April z850 initialized in February



Below-normal



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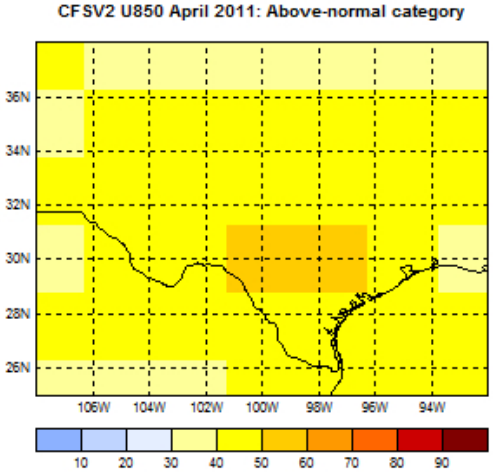
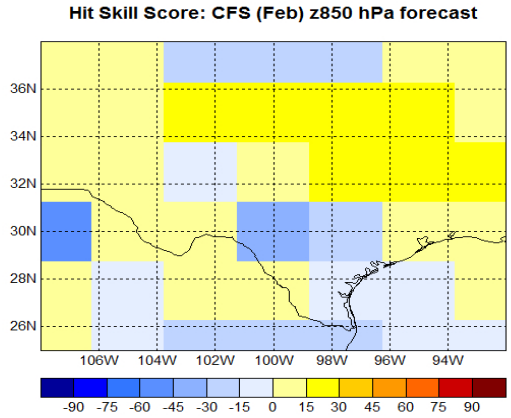


Above-normal



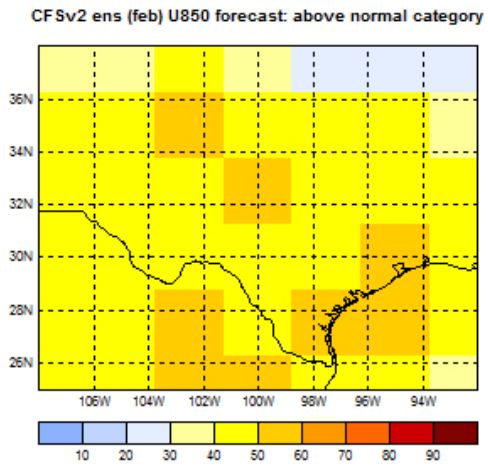
Forecast: weighted towards above normal

Overall skill: Central Texas has skill scores in the 15-30% range. South central region has no skill.

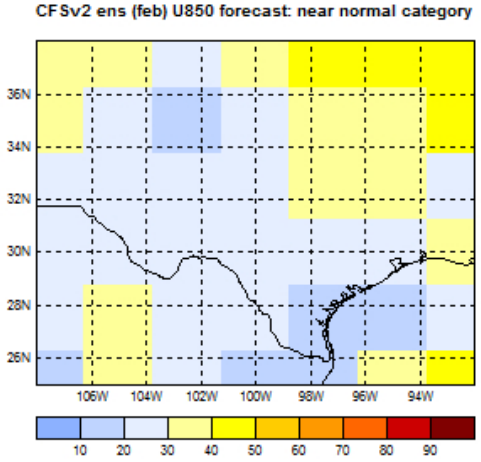
(Source: Fernando et al., in-prep.)

However, CFSv2 full ensemble forecast did not capture the above normal westerly wind anomalies in April 2011:

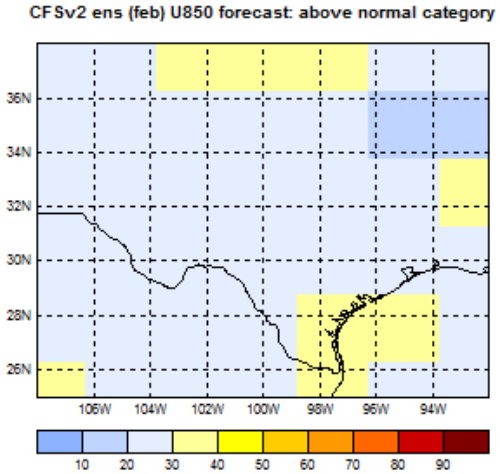
U850 forecast using CFSv2 ensemble forecast of z850 initialized in February



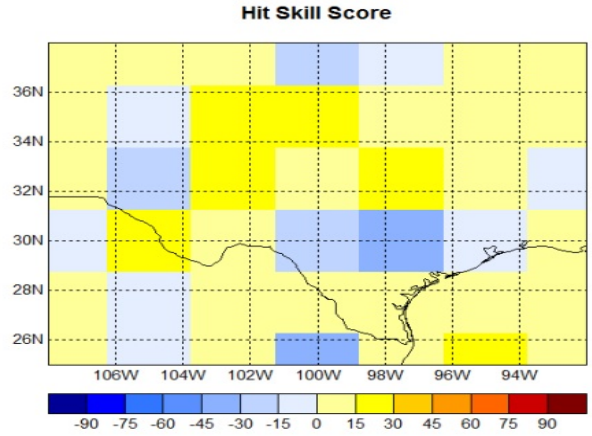
Below-normal



Near-normal



Above-normal



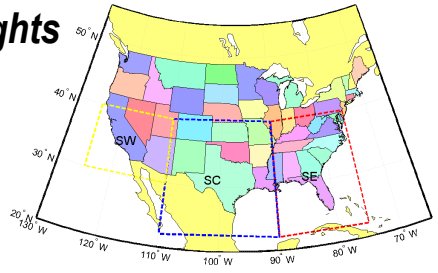
Forecast: weighted towards below normal ☹

Overall skill: Central Texas has skill scores in the 15-30% range. South central and western regions have no skill (based on 1982-2010)

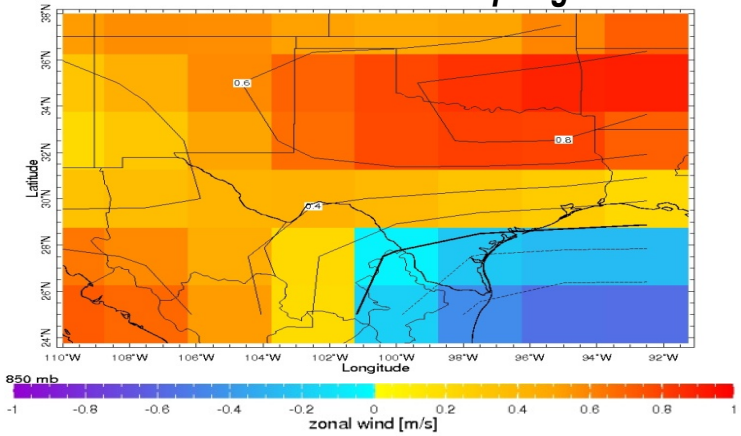
(Source: Fernando et al., in-prep.)

CMIP5 historical runs (Preliminary results)

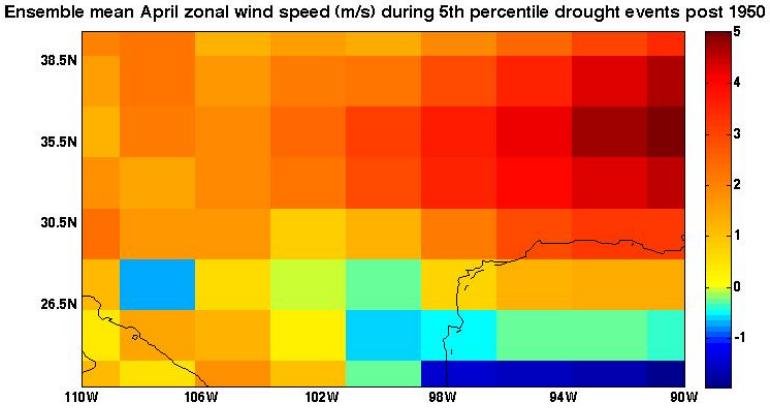
- *Mean 850 hPa zonal winds are too weak in the selected seven CMIP5 models.*
- *Westerly zonal wind anomalies at 850hPa associated with top 5% droughts show a similar spatial pattern to that observed.*

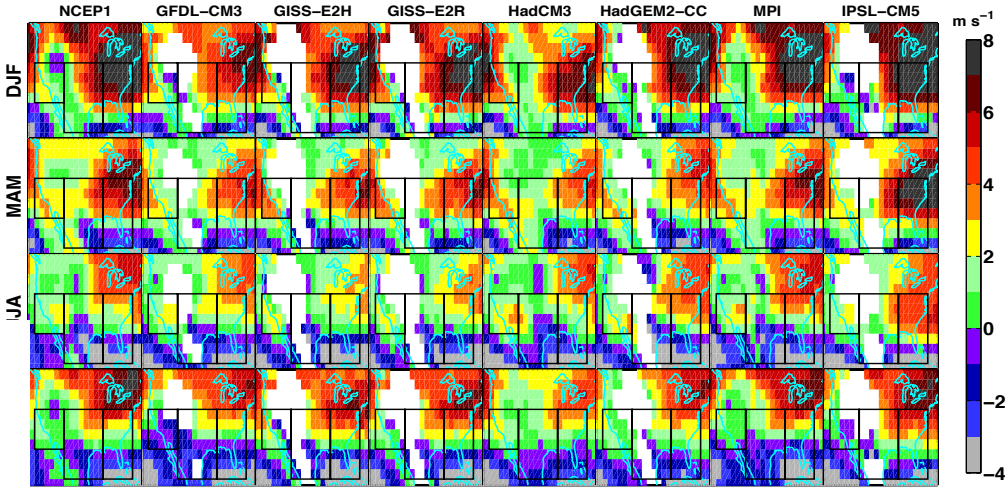


Observed U850 hPa associated with spring-summer droughts



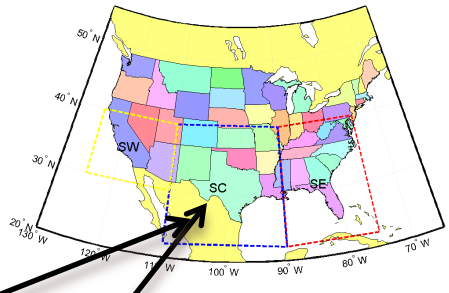
modeled U850 hPa for the 5% droughts post 1950

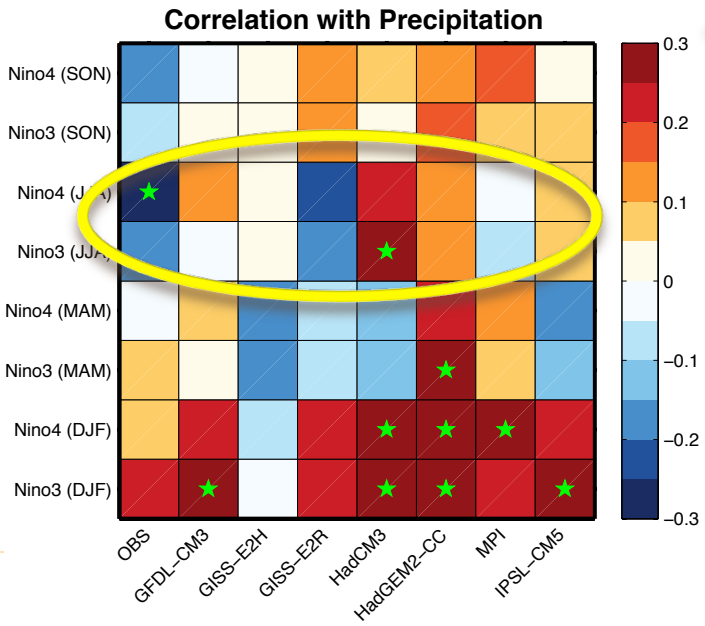


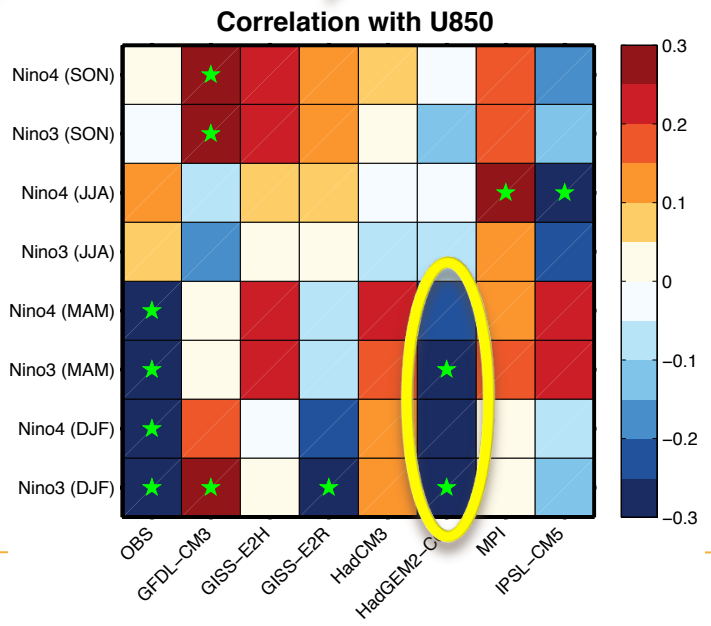


CMIP5 historical runs (Correlation with ENSO):

- *HadGEM2 best capture the correlation between U850 and Niño3 and Niño4 indices in spring, whereas other 6 selected CMIP5 models do not.*
- *Except for GISS-E2R, all other selected CMIP5 models fail to capture the sign of correlation between JJA dry rainfall anomalies and El Niño in summer.*







SUMMARY:

- *A strong increase of CIN due to westerly advection of the warm temperature and surface dryness appear to contribute to the 2011 exceptional drought and the other three strongest droughts in Texas during the past century. This westerly anomalous is correlated to and potentially predictable based on ENSO index in early spring.*

- *While CFSv2 full ensemble and most-likely ensemble forecasts failed to predict the soil moisture deficit during the 2011 summer drought, the CFSv2 most-likely ensemble forecast appear to capture the above-normal westerly winds at 850hPa in spring. We are exploring whether errors in rainfall response to this anomalous large-scale wind pattern or soil moisture feedbacks contribute to the failure of predicting strong soil moisture deficit in summer of 2011.*

- *Based on the historical runs, HadGEM appears to adequately capture the relationship between Niño indices and U850hPa anomalies over Texas in spring, although it fails to capture the observed relationship between Niño indices and rainfall anomalies over Texas for the same season. All other selected 6 CMIP5 models underestimate U850hPa over the SC US in spring and do not capture the correlation between rainfall anomalies and U850hPa over Texas and Niño indices.*